# ON-SITE CLEANING GAS GENERATION FOR PROCESS CHAMBER CLEANING

## BACKGROUND OF THE INVENTION

### Field of the Invention

The present invention relates generally to the field of semiconductor manufacturing. More specifically, the present invention relates to a method of on-site cleaning gas, e.g., F.sub.2, generation for semiconductor and/or flat panel display process chamber cleaning, and a method of eliminating HF from F.sub.2 generator by, for example, cryo condensation.

Description of the Related Art

One of the primary steps in the fabrication of modern semiconductor devices is the formation of a layer or film on a substrate. As is well known in this art, such a layer can be deposited by chemical vapor deposition (CVD). In a conventional plasma-enhanced CVD (PECVD) processes, a controlled plasma is formed using radiofrequency (RF) energy or microwave energy to decompose and/or energize reactive species in reactant gases to produce the desired film.

One problem that arises during such CVD processes is that unwanted deposition occurs on some or all of the processing chamber's interior surfaces, leading to potentially high maintenance costs. With CVD of a desired film onto a substrate, the deposition of undesired residues can occur on any surface, because the reactive gases can diffuse to most parts of the processing chamber, even between cracks and around corners. During subsequent substrate depositions, these residues can accelerate until a continuous film is grown on the undesired parts. Over time, failure to clean the residue from the CVD apparatus often degrades process yield.

When excess deposition starts to interfere with the CVD system's performance, various parts of the chamber can be replaced to remove unwanted accumulations thereon. However, the replacement would potentially increase the maintenance cost. Moreover, such maintenance adversely affects throughput of the CVD system. Therefore, cleaning of the processing chamber is

regularly performed to remove such unwanted residues from the chamber walls, heater, and other process kit parts.

Commonly performed between deposition steps for every substrate (or every n substrates), in situ cleaning procedures using one or more cleaning (i.e., etchant) gases are performed to remove the unwanted residual material accumulated during the deposition process. Common cleaning techniques known to those having ordinary skill in this art include thermal, RF plasma, and microwave plasma techniques.

A radiofrequency plasma cleaning process could use nitrogen trifluoride (NF.sub.3), for example, because such a technique is capable of imparting the high energies required to dissociate a more stable compound. First, NF.sub.3 is flowed into the processing chamber being cleaned. Radiofrequency energy is then applied (e.g., via the substrate processing system's capacitively coupled electrodes), thus generating the fluorine radicals (F*) which remove the unwanted residues from the processing chamber's components. A frequency of 13.56 megahertz (MHz) is commonly used to excite the plasma.

However, the radiofrequency plasma process using NF.sub.3 could be costly, as NF.sub.3 is very expensive. Other gases such as SF.sub.6 and C.sub.2 F.sub.6 are cheaper, but usually cause significant environmental pollution. Therefore, the prior art is deficient in the lack of effective and economic means of cleaning a semiconductor and/or flat panel display process chamber with minimal environmental pollution. Specifically, the

prior art is deficient in the lack of effective means of cleaning a process chamber by generating the cleaning gas, such as, F.sub.2 on site and further delivering the cleaning gas to the chamber so that the HF is eliminated from the F.sub.2 generator by cryo condensation. The present invention fulfills these long-standing needs and desires in the art.

## SUMMARY OF THE INVENTION

Provided herein in one embodiment of the present invention is a method for cleaning a process chamber for semiconductor and/or flat panel display manufacturing. This method comprises the steps of converting a non-cleaning feed gas to a cleaning gas in a remote location and then delivering the cleaning gas to the process chamber for cleaning. This method may further comprise the step of activating the cleaning gas outside the chamber before the delivery of the gas to the chamber.

Also provided herein in another embodiment of the present invention is an alternative method for cleaning a process chamber for semiconductor and/or flat panel display manufacturing. This method comprises the steps of converting a feed gas to a cleaning gas in a remote location, wherein the resulting gas is a mixture of the feed and cleaning gas; transferring the resulting gas mixture to a cold trap, wherein the feed gas is turned into a liquid form, and the cleaning gas remains

in a gaseous form; and delivering the cleaning gas to the process chamber for cleaning. This method may further comprise the steps of pumping the cleaning gas into a storage unit and/or activating the cleaning gas outside the chamber before the delivery of the cleaning gas to the chamber.

Other and further aspects, features, and advantages of the present invention will be apparent from the following description of the embodiments of the invention given for the purpose of disclosure.



## BRIEF DESCRIPTION OF THE DRAWINGS

So that the matter in which the above-recited features, advantages and objects of the invention, as well as others which will become clear, are attained and can be understood in detail, more particular descriptions of the invention briefly summarized above may be had by reference to certain embodiments thereof which are illustrated in the appended drawings. These drawings form a part of the specification. It is to be noted, however, that the appended drawings illustrate embodiments of the invention and therefore are not to be considered limiting in their scope.

**Figure 1** is a schematic drawing in accordance with one embodiment of the present invention. The feed gas (e.g., HF)

is eliminated from the cleaning gas (e.g., F.sub.2) generator by cryo condensation, and then the purified cleaning gas is delivered into a storage unit before its arrival to the PECVD process chamber.

**Figure 2** is a schematic drawing in accordance with another embodiment of the present invention. The feed gas is eliminated from the cleaning gas generator by cryo condensation, and the purified cleaning gas is delivered into a storage unit. The cleaning gas is then activated before its arrival to the PECVD process chamber.

## DETAILED DESCRIPTION OF THE INVENTION

Provided herein in one embodiment of the present invention is a method of on-site cleaning gas generation for a semiconductor and/or flat panel display process chamber cleaning. A cheap feed stock gas, such as HF may be used instead of the expensive NF.sub.3. HF itself does not clean the chamber. However, when HF is electrolyzed, the resulting F.sub.2 may be used as a cleaning gas.

To clean the process chamber, the feed gas (e.g.. HF) is chemically converted to a cleaning gas (F.sub.2) in a remote location (i.e., pump garage area). That is, the F.sub.2 cleaning gas is generated on-site. Then F.sub.2 is delivered to the chamber

for chamber cleaning. Optionally, the cleaning gas F.sub.2 can be activated outside the chamber to increase the cleaning efficiency via a remote plasma source (RPS). During the activation, F.sub.2 is chemically turned into 2F in the plasma excitation environment.

A typical method of generating F.sub.2 from HF is electrolysis (HF ----> F.sub.2 + H.sub.2). After electrolysis, the F.sub.2 and HF in gaseous form are transferred from the generator to a cold trap cylinder, wherein the F.sub.2 and HF are separated (Figures 1 and 2). Specifically, the cold trap turns HF into a liquid form, while F.sub.2 is pumped into the 100-liter storage cylinder, and further supplied to the process chamber. The byproduct of the electrolysis H.sub.2 is sent to an exhaust system.

The present method reduces the cost of chamber cleaning and eliminates the use of global warming gas. Due to safety concerns, F.sub.2 is generated on-demand to minimize the need for storage. However, a mini-storage device can be used. Additionally, the method of eliminating HF from the generated cleaning gas by cryo condensation has several advantages over the state-of-art methods which uses sodium fluoride trap. For example, the changing cold trap does not require any maintenance; and secondly, sodium contamination is eliminated from the gas line.

As described above, provided herein is a method for cleaning a process chamber for semiconductor and/or flat panel

display manufacturing. This method comprises the steps of converting a non-cleaning feed gas to a cleaning gas in a remote location and then delivering the cleaning gas to the process chamber for cleaning. Such a method may further comprise the step of activating the cleaning gas outside the chamber before the delivery of the gas to the chamber. Specifically, the activation may be performed through a remote plasma source, a heat source, or an electrical source. Representative examples of a remote plasma source include a microwave energy source or a radiofrequency energy source.

In this method, an example of the non-cleaning feed gas is HF, and the generated cleaning gas is F.sub.2. In one aspect, the conversion is done through electrolysis.

Also provided herein in another embodiment of the present invention is an alternative method for cleaning a process chamber for semiconductor and/or flat panel display manufacturing. This method comprises the steps of converting a feed gas to a cleaning gas in a remote location, wherein the resulting gas is a mixture of the feed and cleaning gas; transferring the resulting gas mixture to a cold trap, wherein the feed gas is turned into a liquid form, and the cleaning gas remains in a gaseous form; and delivering the cleaning gas to the process chamber for cleaning. This method may further comprise the steps of pumping the cleaning gas into a storage unit and/or activating the cleaning gas outside the chamber before the delivery of the gas to the chamber. Specifically, the activation may be performed through a remote plasma source, a heat

source, or an electrical source. Representative examples of remote plasma sources familiar to those having ordinary skill in this art include a microwave energy source or a radiofrequency energy source.

Further in this method, an example of the non-cleaning feed gas is HF, and the generated cleaning gas is F.sub.2. Usually, the conversion is done through electrolysis.

One skilled in the art will readily appreciate that the present invention is well adapted to carry out the objects and obtain the ends and advantages mentioned, as well as those inherent therein. It will be apparent to those skilled in the art that various modifications and variations can be made in practicing the present invention without departing from the spirit or scope of the invention. Changes therein and other uses will occur to those skilled in the art which are encompassed within the spirit of the invention as defined by the scope of the claims.